MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

EME2146 – APPLIED THERMODYNAMICS

(ME)

05 MARCH 2018
09.00 a.m. - 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of five pages (including the cover page) with four questions.

2. Answer ALL four questions.

3. Each question carries 25 marks and the distribution of the marks for each question is given in brackets [ ].

4. Write all your answers in the answer booklet provided.

5. Property-tables booklet is provided for your reference.

Question 1

Propane gas (C_3H_8) is delivered at a constant rate of 22 g/s. It is mixed with 200 % excess air (dry air) at same the temperature of 25 °C. The mixture is combusted completely at the constant pressure of 100 kPa. The product gases of combustion exit the chamber at 1000 K.

Substance	N_2	O_2	CO_2	H_2O	C_3H_8
Molecular weight (kg/kmol)	28	32	44	18	44

The dry air composition: nitrogen to oxygen ratio by mole = 3.76.

a. Write the stoichiometric combustion equation.

[3 marks]

b. Write the combustion equation with 200% excess air.

[3 marks]

c. Calculate the air-fuel ratio.

[3 marks]

d. Find the enthalpy of formation for C_3H_8, CO_2, and H_2O at 298 K and 100 kPa from the property table.

[3 marks]

e. Calculate the change of enthalpy per kmol of C_3H_8 for CO_2, H_2O, O_2, and N_2 from 298 K to 1000 K at 100 kPa.

[4 marks]

f. Calculate the rate of heat transfer from the combustion in kW.

[4 marks]

g. Calculate the amount of water vapor (in kg) condensed after 5 minutes if the product gaseous are cooled to 20°C at 100 kPa. The saturated water vapor pressure at 20°C is 2.3392 kPa.

[5 marks]

Continued...

Question 2

A single-cylinder spark-ignition internal combustion engine is assumed to operate on an ideal Otto cycle. Air and fuel are mixed and enter the engine at the atmospheric conditions, 100 kPa and 300 K. The total mass of air-fuel mixture is 2 g. The air-fuel mixture is compressed isentropically (compression ratio is 10), where temperature and specific volume are related as $Tv^{\gamma-1}$ = constant. The amount of heat addition per cycle is 1440 J. Assume idea gas of the air-fuel mixture, the constant volume specific heat of the air-fuel mixture, $c_v = 720$ J/kg·K, the specific heat ratio, $\gamma = 1.4$, and the specific heat difference, $c_p - c_v = R$.

a. Sketch and label the $T - s$ diagram of the cycle.

[2 marks]

b. Sketch and label the $p - v$ diagram of the cycle.

[2 marks]

c. Find temperature after compression.

[3 marks]

d. Determine the maximum temperature of the cycle.

[3 marks]

e. Find the exit temperature of the exhaust gases.

[3 marks]

f. Calculate the amount of heat rejected per cycle in J.

[3 marks]

g. Calculate the amount of net work output per cycle in J.

[3 marks]

h. Determine the thermal efficiency of the cycle.

[3 marks]

i. Find the cylinder volume of the engine in liter.

[3 marks]

Continued...

Question 3

a. A rigid tank, of 0.5 m^3 volume, contains an ideal-gas mixture at 300 K. The mixture is made up of 2.4 kg of gas A and 1.4 kg of gas B, the molecular weights of which are $M_A = 32.0$ kg/kmole and $M_B = 28.0$ kg/kmole, respectively.

i. Determine the mass fraction of A and B.

[3 marks]

ii. Determine the mole fraction of A and B.

[5 marks]

iii. Determine the molecular weight of the mixture.

[2 marks]

iv. Determine the total pressure p_{tot} as well as the partial pressures p_A and p_B. The universal gas constant R has the value of 8.31 kJ/kmole·K.

[3 marks]

b. A cylinder fitted with a movable frictionless piston contains a mixture of dry air and water vapor. The piston is arranged in such a way that the (total) pressure inside the cylinder remains constant at 100 kPa. Initially, the temperature of the mixture is 40 °C, its dew-point temperature being 25 °C.

i. Determine the initial relative humidity, ϕ_1, of the mixture.

[3 marks]

ii. Determine the initial humidity ratio, ω_1, of the mixture.

[3 marks]

Now, the mixture inside the cylinder is cooled to the final temperature T_2 in order to partially condense the vapor in the mixture and to reduce its vapor content by 50% on a mass basis.

iii. What is the humidity ratio, ω_2, of the remaining mixture?

[2 marks]

iv. What is the final temperature T_2?

[4 marks]

Continued...

Question 4

a. In a steady-state steady-flow process, a gaseous substance expands inside a device which is thermally insulated from its surroundings, enabling it to deliver mechanical work. The substance enters the device with $T_1 = 1.9T_{\text{cr}}$ and $p_1 = 4.0p_{\text{cr}}$; it exits with $T_2 = 1.2T_{\text{cr}}$ and $p_2 = 2.0p_{\text{cr}}$. The constant-pressure specific heat of the substance is equal to $3.85R$, where R is the universal gas constant. What is the work delivered by the device, w, for each unit amount of the substance? Express your answer in terms of the gas constant R and the critical temperature T_{cr}.

[6 marks]

b. Write out the defining equations of the isothermal compressibility κ_T and isentropic (adiabatic) compressibility κ_s of a pure substance.

[4 marks]

c. A gaseous substance is transformed from its initial state (p_0, v_0) to the final state (p_1, v_1), where $p_1 = 2p_0$ and $v_1 = 2v_0$, by a process X in which its specific volume and pressure are related by the equation

$$\frac{p}{p_0} = 1 + \left(\frac{v}{v_0} - 1\right)^2$$

i. Determine the work done by the substance during the process X. Express your result in terms of p_0 and v_0.

[3 marks]

Now, it is also known that the specific Helmholtz function of the substance is given by

$$a = K - RT_0 \ln\left(\frac{v}{v_0}\right) - \frac{RT_0}{m}\left[\left(\frac{T}{T_0}\right)^m - 1\right]\left(\frac{v}{v_0}\right)$$

where K, R, and m are positive constants, and T_0 is the substance's temperature at the initial state.

ii. Determine the change in the internal energy of the substance, $u_1 - u_0$, and the heat transfer during the process X. Express your results in terms of p_0, v_0, and m only.

[12 marks]

End of Paper